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Insect wings as retrospective/accidental/forensic dosimeters: An optically stimulated luminescence investigation

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HIGHLIGHTS

- OSL of insects' wings are explored towards their use in retrospective/accidental/forensic dosimetry.
- OSL dose response can be fitted with linear functions for doses up to 2 kGy.
- Loss of OSL signal (fading) is imperceptible several days after their irradiation.
- A novel single aliquot measurement protocol is successfully tested for the dose recovery.

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ABSTRACT

Estimation of the radiation released during nuclear accidents or radiological terrorist events is imperative for the prediction of health effects following such an exposure. In addition, in several cases there is a need to identify the prior presence of radioactive materials at buildings or sites (nuclear forensics). To this direction, several materials have been the research object of numerous studies the last decade in an attempt to identify potentially new retrospective/accidental/forensic dosimeters.

However, the studies targeting biological materials are limited and their majority is mainly focused on the luminescence behavior of human biological material. Consequently, the use of such materials in retrospective dosimetry presumes the exposure of humans in the radiation field. The present work constitutes the first attempt to seek non-human biological materials, which can be found in nature in abundance or in/on other living organisms. To this end, the present work investigates the basic optically stimulated luminescence behavior of **insect wings**, which exhibit several advantages compared to other materials. Insects are ubiquitous, have a short life expectancy and exhibit a low decomposition rate after their death.

Findings of the present study are encouraging towards the potential use of insects' wings at retrospective/accidental/forensic dosimetry, since they exhibit linear OSL response over a wide dose range and imperceptible loss of signal several days after their irradiation when they are kept in dark. On the other hand, the calculated lower detection limit is not low enough to allow their use as emergency dosimeters when individuals are exposed to non-lethal doses. In addition, wings exhibit strong optical fading when they are exposed to daylight and thus special care should be taken during the sampling procedure in order to use the wings as accidental/forensic dosimeters, by seeking (dead) insects in dark places, such as behind furniture, equipment or in air-shafts.

Finally, a new single aliquot measurement protocol is also successfully tested on the wings for the dose estimation, while further work is in progress to validate it on other (heat-sensitive) materials as well.

1. Introduction

Incidents which involve the unexpected release of radiation, such as radiation accidents or leakages, can take place due to human error, equipment failure or other reasons despite all the

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precautionary measures taken (e.g. Pradhan et al., 2012; Sahiner et al., 2015). The most recent example of such an accident at a nuclear power plant is the Fukushima Daiichi Nuclear Disaster, in Japan in 2011, while the risk of radiological terrorist events (e.g. *dirty bomb*) is not negligible.

It is apparent that the (rapid) assessment of the radiation dose is very important for the prediction of health effects following an exposure in such events (Mrozik et al., 2014), using several methods such as Electron Paramagnetic Resonance (EPR), Thermoluminescence (TL) and Optically Stimulated Luminescence (OSL). For this purpose, retrospective dosimetry constitutes the most important tool of accidental dosimetry when there is no dose data available (e.g. from personal dosimeters) (Mesterhazy et al., 2012). At the same time, researchers also seek materials appropriate for forensic purposes, which would allow to identify the prior presence of radioactive materials at buildings, sites or even vehicles (e.g. Inrig et al., 2008; Schwantes et al., 2009; Spooner and Smith, 2008).

For this purpose, research is conducted on the luminescence behavior of several ubiquitous materials seeking those that exhibit the features of a good dosimeter allowing the evaluation of the dose after a radiation incident, for personal dosimetry and/or forensic purposes (e.g. Trompier et al., 2011). Electronic components (e.g. Bassinet et al., 2014a; Ekendahl et al., 2015; Inrig et al., 2008), credit cards (e.g. Mathur et al., 2007; Pascu et al., 2013), glass displays (e.g. Bassinet et al., 2014b; Discher et al., 2013; Discher and Woda, 2014) and other commonplace materials have been studied with OSL or TL towards this direction.

The last decade there is a trend towards the potential use of biological materials as dosimeters for retrospective dosimetry. Tooth enamel (e.g. Meriç et al., 2015; Romanyukha et al., 2014) and fingernails (e.g. Sahiner et al., 2015; Trompier et al., 2007) are typical examples. However, all relative studies focus on human biological materials and their use at retrospective dosimetry requires human exposure in radiation.

Consequently, it would be very interesting to seek non-human biological materials, which can be found in nature in abundance or in/on other living organisms. To this effect, the present work investigates the possibility of using **insects**, and specifically their **wings**, as dosimeters for accidental or forensic purposes.

The above idea seems advantageous compared to human biological materials for several reasons. First of all, insects are indeed ubiquitous and can be found in houses, laboratories, even in nuclear plants. In addition, many of them (especially those of the present study) have very short life expectancy (few weeks' time) (e.g. Agarwal and Sohal, 1994; Van Buskirk, 1987) which means that the natural dose that they have received is negligible. Consequently, any signal recorded after a radiation-release incident can entirely be attributed to the absorbed dose, without the need to estimate the natural dose in order to correct the laboratory measured total absorbed dose. Finally, deceased insects, being exoskeleton animals, exhibit a very low decomposition rate due to their resistant body components (e.g. Meyers, 1995). As a result, their body and wings remain intact for a relatively long period after their death, allowing their potential use as dosimeters even several weeks after their death.

To this direction, the scope of the present study is to investigate the basic luminescence behavior of the wings of two commonly-found **fly** species by means of OSL in order to explore their potential use as accidental/retrospective/forensic dosimeters.

2. Materials and methods

2.1. Insect selection and details

The species of flies selected for the present study were the *Musca domestica* belonging to the order Diptera, commonly known as housefly, and the *Sympetrum striolatum* belonging to the order Odonata, commonly known as dragonfly. Fig. 1 illustrates wings of the above flies, used in the present study. It should be noted that wings were sampled from dead insects of the above species found in the basement of the building.

Insect wings are composed primarily of cuticle, a multi-layered material consisting of **chitin** microfibers embedded in a protein matrix (Combes, 2010). Chitin is a naturally abundant mucopolysaccharide and is the supporting material of crustaceans, insects, etc (Kumar, 2000). Several studies have explored the behavior of chitin by means of ESR (e.g. Bruscato et al., 1978; Muzzarelli et al., 1979) and certified the existence of a paramagnetic species. In addition, more recent studies involved the thermoluminescence behavior of shellfish (e.g. Ahna et al., 2013; Bhatti et al., 2008) and concluded that it is possible to identify irradiated shellfish by means of TL.

According to the above, it seems that chitin is the key component that produces the ESR or TL signal, which is also accepted by Gosting et al. (1991), who state that the radiation-induced ESR signal in the exoskeleton of shrimp appears to be related to the chitin content. Thus, since the wings of the insects are composed of chitin, it is expected that they will also produce an OSL signal.

2.2. Sample preparation

The wings of the studied insects were carefully and gently removed using a scalpel in order to be obtained entirely intact. All wings were washed with distilled water in an ultrasonic bath in order to remove any contamination from their surface and were left to dry in room temperature. Finally, they were attached intact with a drop of silicon grease in stainless steel cups in order to conduct the OSL measurements.

2.3. Instruments and methods

All continuous wave OSL measurements were conducted using a Riso TL/OSL reader (model TL/OSL-DA-15), equipped with a $^{90}Sr/^{90}Y$ beta particle source capable of delivering a nominal dose rate of about 3.46 Gy/min at the time of the measurements. A Thorn-EMI 9235QA photomultiplier tube with the appropriate filter, namely a Hoya U-340 with maximum transmittance at approximately 340 nm and full width at half maximum (FWHM) about 80 nm, was used for light detection.

The system is also equipped with blue LEDs emitting at 470 nm arranged in six clusters each containing seven individual LEDs (maximum total power ~40 mW/cm^2 at the sample) (Botter-Jensen

Fig. 1. Images of the wings studied; dragonfly (top) and housefly (bottom).